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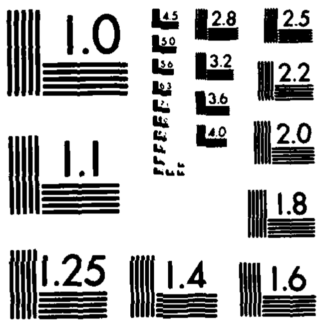

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OFFICE OF NAVAL RESEARCH

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FRENCH PLANS FOR FIFTH GENERATION COMPUTER SYSTEMS

J.F. BLACKBURN

7 DECEMBER 1984

UNITED STATES OF AMERICA

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Since the October 1981 announcement of Japan's Fifth Generation Project, the French scientific and industrial communities have shown an increased interest in artificial intelligence languages, expert systems, man-computer interaction, novel computer structures, and knowledge-based computer systems.

This report describes the French effort and includes a survey of the various French initiatives in hardware and software technologies aimed toward fifth generation computer systems and applications. These separate projects

are the National Projects, the Joint Research Projects, the Centre National de Recherche Scientifique Cooperative Research Groups, and the Thematic Research Program.

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FRENCH PLANS FOR FIFTH GENERATION COMPUTER SYSTEMS

Since the October 1981 announcement of Japan's Fifth Generation Project, the French scientific and industrial communities have shown an increased interest in artificial intelligence (AI) languages, expert systems, man-computer interaction, novel computer structures, and knowledge-based computer systems.

The Japanese Fifth Generation Program is heavily oriented toward AI applications. France is currently active in artificial intelligence and is developing hardware and software components and structures for the design and implementation of AI applications, which are expected to increase in importance during the next decade.

Although there is no overall plan in France that corresponds precisely to Japan's, parts of the French effort correspond to the Japanese program (see *ESN* 38-3:125-127 [1984]). And while the Japanese announcement has been a factor in ministerial and industrial awareness of the potential significance of AI applications, most of the ongoing projects in France originate from earlier work. It should be noted, for example, that the Prolog language chosen by the Japanese for their Fifth Generation Project originated mainly in France.

There is no single centrally managed project in France that covers all the facets of the Japanese Program. The Alvey Program (*ESN* 39-1:12-13 [1985]) in the UK and the European Strategic Planning of Research and Development in Information Technology (ESPRIT) program (*ESN* 38-2:69-71 [1984]) of the European Economic Community are somewhat closer in organization to the Japanese program. In France, research and development efforts corresponding to the various facets consist of distinct projects that complement each other in technical content and in scientific and industrial objectives.

This report describes the French effort and includes a survey of the various French initiatives in hardware and software technologies aimed toward fifth generation computer systems and applications. These separate projects are the National Projects, the Joint Research Projects, the Centre National de Recherche Scientifique (CNRS) Cooperative Research Groups (GRECO), and the Thematic Research Program.

The National Projects

The French Ministry of Research launched the concept of "filière" (a French expression for "the whole mill") in May 1981. The purpose was to make the French electronics industry successful and competitive in French and world markets. In order to do so, it was believed that the French electronics industry should master all the technological components from basic technologies to software products and end products incorporating hardware and software subsystems. These filières cover vertical chains of production from raw materials to finished products in sectors including energy, biotechnology, and electronics. The government attempts to coordinate the overall technical direction of the filières by promoting joint research activities linking industry with large research organizations and universities.

To implement the policy a committee was appointed in the fall of 1981 to assess strong and weak points of the French industry in electronics, computers, software, and services and to make proposals for action. The committee concluded its work in May 1982. Proposals were made for industrial strategy, the role of nationalized companies (Bull, Compagnie Général d'Electricité [CGE], Matra, Thompson-CSF), education, and research and development. One proposal was to launch several R&D projects, called national projects, through which industry and public research laboratories should collaborate over a period of about 3 years in the development of products based on advanced research prototypes projects. This objective is quite similar to that of the Alvey and ESPRIT Programs.

The following themes for National Projects have been defined:

1. Very large scale integration/computer-aided design (VLSI/CAD) tools
2. Software engineering
3. Computer-aided design/computer-aided manufacturing (CAD/CAM)
4. Computer-aided instruction
5. Automatic translation
6. Display hardware
7. Basic components and subsystems for microcomputers and minicomputers
8. A supercomputer project managed by the French Ministry of Defense.

These projects began in 1983, and most of them are now in the detailed specification stage. Descriptions of their actual content and organization should be publicly released by early 1985.

About 150 professionals from academia and public research and 60 professionals from industry are participating in the national projects. More than 20 companies, more than a dozen departments of government, and about a dozen universities are involved in the national projects.

The work in software engineering is a good example of a National Project growing out of previous work. Software engineering is recognized as a key factor in industrial and economic development. In 1978 the first software engineering curriculum appeared in France at the university of Rennes, and a national software engineering committee was established. The committee is responsible for: determining orientations and priorities for R&D in software engineering and making recommendations for projects to be funded by the Agence de l'Informatique.

The committee consists of experts drawn from public research laboratories, computer manufacturers, software houses, and users from industry (electronics, avionics, automotive industry, and others).

During the past 4 years, about 50 R&D projects have been funded, covering the whole spectrum of software engineering tools, techniques, and procedures. These projects concern basic or applied research and are most often joint ventures among industry and public research laboratories. Three competing projects were funded in 1981 in the detailed specification of a common environment on which forthcoming software engineering environments could be based. In 1983 a choice was made among them which led to the two projects on which the present French software engineering work is based.

The first project, called Projet National Génie Logical was launched in 1983 concurrently with six others covering key areas of information technology. It consists of two complementary subprojects. The first one, known as EMERAUDE, concerns the refinement and actual implementation of the common environment mentioned above. The second one--known as the Tools Project--concerns the development of specific tools meant to be integrated by means of the EMERAUDE environment and the implementation of fully integrated software engineering factories especially designed for specific languages and development procedures. Most of the candidate tools originated from the projects funded in earlier software engineering requests for proposals. This National Project has been planned for a 3-year period, and it is expected to lead to commercial products exhibiting a technology jump when they are released. Participants are mainly industries with some collaboration from public research laboratories. The French Ministry of Industry shares roughly 50 percent of the cost with industrial participants.

The second main cooperative project, CONCERTO, follows a different line. Although its purpose and structure are similar to those of the National Project, it is more deliberately long range. It is not intended to lead to full-fledged products when it is completed at the end of 1985. Instead, working prototypes based on real-life investigations should lead to implementations, after refining and pruning. The CONCERTO project is conducted by Centre National d'Etudes des Télécommunications (CNET) in cooperation with

several public research laboratories and software houses in Grenoble, Lannion, Paris, and Toulouse.

Software engineering projects are complemented by other fundamental or applied research projects known as Joint Research Projects.

The Joint Research Projects

Since the National Projects are essentially technology-transfer projects, they have been complemented by long-range research initiatives. After the beginning of the National Projects in 1983, the main research organizations started several fundamental research cooperation projects dealing with basic computer engineering. One objective of these projects is to concentrate the resources of many research groups on a common topic relevant to fifth generation issues. Included among the projects are advanced programming; basic problems relating to concurrency, cooperation, and communication in computer systems; fifth generation database management systems; the various facets of AI; advanced electronic components; and man-machine communication.

Participants in these projects are the main research organizations in France, including CNRS, CNET, Institut National de Recherche en Informatique et en Automatique (INRIA), universities, and the large industrial laboratories performing basic research (Bull, CGE, Thompson-CSF).

GRECO and Thematic Research Programs

In addition to the two categories of projects described above--which draw the main part of public funds for R&D in computer science and engineering--there are also the cooperative research groups managed by CNRS. These groups gather, less formally than in the case of National Projects, various laboratories conducting research in the same field, some of which relate to fifth generation issues.

The main funding sources for the CNRS programs are:

- The Ministry of Industry and Research, including its research and technology budget and Agence National pour la Valorization de la Recherche
- French Telecom, including CNET
- Agence de l'Informatique
- The Ministry of Defense, including Direction de Recherche d'Etude et Technique (DRET), somewhat similar to the Defense Advanced Research Projects Agency in the US.

GRECO is made up of cooperative groups under the management of CNRS. The participants in the GRECO program are the CNRS laboratories, CNET, INRIA, Institut de Recherche en Informatique et Systems Aléatoire (IRISA), and the following universities: Paris 6, 7, 8, and 11; Grenoble; Nancy; Rennes; Toulouse; Bordeaux; Poitiers; Matz; and Strasbourg. The industrial firms Bull, CGE, and Thompson-CSF also have research and development programs that are a part of the CNRS program.

In GRECO the main research topics relevant to fifth generation computing are languages, translations, specifications, proofs of correctness, and transformations. Among the readily available tools are a Digital Equipment Corporation VAX system in Bordeaux running the operating system MULTICS, and an SM90 system open to research groups. The SM90 system uses Motorola 68000 microprocessors as components. The coordinator is R. Cori of the University of Bordeaux.

GRECO "PAROLE" is a speech synthesis and recognition program, coordinated by J.-P. Hatton (University of Nancy). GRECO "Calcul Formel" is a program of research on symbolic manipulation coordinated by D. Lazard (University of Poitiers). GRECO C^3 is a military program on communication, cooperation, and control coordinated by Messers. G. Roucairol and M. Nivat in the Ministry of Defense. A program on advanced robotics is coordinated by G. Giralt, Laboratoire d'Automatique et d'Analyse des Systemes (LAAS, Toulouse) and

includes participation from many other CNRS locations (see *ESN* 36-11, 37-1, 37-3, and 37-5).

Other CNRS programs include a database management system for fifth generation computers. This effort deals with new applications and functions and is done in collaboration with CGE and Comptoir d'Etudes Radio Techniques. Relational databases are not properly organized to handle varied information such as graphics and documents. A project to identify the needs of databases for these new applications began in January 1982. CNRS has had an artificial intelligence program since 1979. Its application in robotics is under way at INRIA, LAAS, Laboratoire d'Informatique pour Mechanique et les Sciences de l'Ingenieur (LIMSI), and IRISA (*ESN* 36-11, 37-1, 37-3, 37-5, and 38-8). The use of artificial intelligence in designing programming languages--including logic and functional programming--is especially active at INRIA, Rocquencourt.

The work in robotics research is of very high quality. Visual sensing is the major emphasis at INRIA, Rocquencourt. Researchers elsewhere have been largely concerned with two-dimensional problems of image analysis and understanding. At INRIA the need for three-dimensional scene analysis in robotics has been recognized and is a major research effort. New sensors and new methods of representing three-dimensional objects are needed. Among the most promising sensors are the geometric sensors which provide, in a reference frame, the Cartesian coordinates of points lying on the surface of an object. The sensors give some intrinsic information about the shape of the object and are less dependent on the environment than, for example, a camera which depends on the level of illumination.

Most such sensors use a structural light such as a laser beam, but tactile, optical, and acoustical devices also can provide geometrical information about shapes. In each case, a number of points on the surface of an object are measured and combined with other information, such as normals to the surface. With a large number of such points the shape of the object is determined.

INRIA has developed a polyhedral representation of objects. An object is represented by a set of three coordinates of points lying on its surface, with a spatial data structure linking them, precisely defined as a graph whose vertices are the measured points and whose edges join the points which are related in some sense. Structures that have the fewest edges and that preserve the topology of the surface play an important role. Such a minimal structure is a polyhedron with the measured points as vertices. Polyhedra can approximate any kind of shape. The storage requirement is proportional to the number of points.

Based on Delaunoy triangulation and an algorithm developed by J.D. Boissonnat, the INRIA researchers have been able to overcome the problems and have succeeded in approximating the shape of target objects.

The mass properties can be computed by looking at the mass properties of the set of interior tetrahedra. The equilibrium positions are obtained by looking for the faces of the convex hulls of the object, which is approximated by the boundary of the Delaunoy triangulation. The hulls contain in their interior the normal projection onto them of the center of mass.

The interior tetrahedra constitute a mesh which can be used to perform stress and thermal analysis using finite-element techniques.

At IRISA, Rennes, the two principal areas of research in robotics are in sensing the environment and controlling the robot. In sensing the environment the robot must identify:

- An obstacle--an object preventing the completion of a task.
- A target--any object on which the robot must act instantly to complete a task.

At IRISA, emphasis has been mainly on local control loops. The approach

can be described as follows: assume a target that can be gripped and a grasping arm in an area with obstacles. The proximity sensors are placed in the pincers to permit centering, straightening, and movement. An observation site, CI; a direction of observation, DI; a signal, SI (combination of elementary signals); an action site, XI; and a direction of action, OI, are associated with each sensor or group of sensors. Between two successive times, KT and (K+1)T, the desired elementary action is to move the point XI toward the point XI+WIOI, where WI is a function of SI. The specification of XI, OI, FI, and SI determine the character of each elementary function (repulsion or attraction) as well as the dynamics of the system. The incremental control required is the combination of translation and rotation needed between KT and (K+1)T to satisfy all constraints required by the desired elementary actions.

In most cases an explicit solution can be found with little computation. Using signals from optical sensors directly furnishes a repulsion corresponding to a Newtonian potential, and continuity with gripping is assured by the choice of certain combinations (CI, DI, XI, OI, WI). For bi-digital or tri-digital grippers, the choice results naturally from the geometry adopted for the fingers and the contact sensors.

Control of Robots

To improve the accuracy of manipulators, controllers must be designed to allow reliable, high-velocity movement. Moving an effector to a final position with a given dynamical behavior or tracking a desired trajectory are classical control problems. Difficulties arise at high velocity when the required behavior must be independent of parameters such as the payload and the location of the effector. If the control is handled by a fixed, linear, monodimensional servo system on each joint, the desired accuracy generally cannot be achieved for high-velocity motions.

An alternative is to derive dynamic control algorithms that take into account coupling and nonlinearities by using a dynamic model of the manipulator, including gravity, inertial, centrifugal and coriolis forces, and torques. One approach is to precompensate for nonlinear terms using a theoretical model with a feed-forward loop. In case the model is precisely known, a linear decoupled feedback may be enough to assign the dynamics of the closed-loop system. Control systems using a dynamic model of the manipulator have drawbacks: real-time computation is costly, accuracy of the system may be degraded by modeling errors, and adaptation to variations and drifts is not certain even if the parameters of the basic model have been well defined.

The objective of a study at IRISA was to test several alternatives to the classic technique. A direct adaptive control algorithm was applied in one case and an indirect adaptive control in the other. The algorithms have been studied for linear systems. Modeling a manipulator joint by a stationary linear system would be satisfactory for small and slow motions. However, for large and fast motions a linear model of the joint was considered nonstationary. The variation of the model coefficients comes from nonlinearities and coupling terms. To track the nonstationary characteristics of the model, identification algorithms with gains never decreasing to zero were used. The working hypothesis is that variations of the model are slow compared with the dynamics of the adaptation.

Simulation results were obtained by applying direct and indirect adaptive control algorithms to each of two manipulator systems. The first manipulator was a three-link cylindrical coordinate type. The second was a three-link, three-joint (two rotations and one translation) manipulator.

Adaptive techniques are inconvenient primarily because they were developed for linear systems, but robots are nonlinear systems. Therefore, it is difficult to analyze precisely and theoretically the results of such controls.

Thus, research at IRISA is oriented toward "robust" control techniques, which are nonlinear (variable gain) with reference models. Simulation tests will soon be carried out with a fast industrial robot.

At LAAS, Toulouse, a nonspecialized mobile robot called HILARE is equipped with multisensor systems and uses a multilevel computer and decision system. The machine has microprocessors for locomotion control, ultrasonics, camera control, image preprocessing, and communication. Higher level processing of information is by a larger local computer; computers at Paris and Montpelier are back-up. HILARE is intended to serve as an experimental support vehicle.

The perception system for the three-dimensional universe of the robot combines information received from a two-dimensional video and from a laser telemeter giving the depth. Two coordinates of a point can be derived from the tilt of the mirrors used to deflect a laser beam onto the target. The third coordinate is determined by the travel time of the laser beam.

The system must be able to find the position and orientation of obstacles, which are always treated as polyhedrons. The system must also be able to recognize objects in a room, which requires complex pattern recognition.

The video signal from the camera is coded over several levels of grey. From the coded image, the contours of objects and adjacent objects are determined. The information from the camera is transmitted to a higher level of the computer and decision system and combined with the laser range information. The telemeter is coupled to the camera so that their optical axes are in agreement. The entire apparatus is mounted on a turntable on the robot. Commands to the motors used to deflect the laser beam are based on data from the microprocessor associated with image processing (INTEL 8030) or from the higher level decision center. The number of measurements by the telemeter are reduced through using only information in the zones where a change of direction of a contour is detected; thus corners of an obstacle or object are located.

All obstacles are assumed to be polyhedral and are represented in two dimensions by polygons or parts of polygons. The main objectives in path planning are to create a structure composed of polygonal cells and to construct a graph connecting those cells to transform the geometric model into a topological one. The four steps are perception, space structuring, path search, and path execution.

A system to navigate a mobile robot has been written in APL programming language and implemented on an IBM 3033 linked to a 16-bit minicomputer (MITRA 15). The microcomputer is in turn linked to the on-board, five-microcomputer structure (INTEL 8085) controlling the robot's motors and sensors. The system has been tested for many obstacle configurations.

The preceding examples are indicative of the level of research in robotics in France. Robotics is one of the two most important areas in which AI is currently applied. The other important area is expert systems, in which logic programming plays an important part. It has already been mentioned that the Prolog language had its origin in France--and in the UK. This is the foremost logic programming language in use today, and it is basic in the Japanese Fifth Generation Computer Program.

Conclusion

The French program is comprehensive. Like the British Alvey Program it is supposed to be complementary to ESPRIT. However, when compared to the British program it suffers from lack of centralized coordination and control. The program is multifaceted and the lines of control are unclear. For example, the Agence de l'Informatique gets direction from at least three agencies: CNRS, Direction des Affaires Industrielles et Internationales, and Direction des Industries Electroniques et Informatiques.

A comprehensive technical evaluation of the program is not possible now.

This may be possible in 1985 when more detail about the specific projects is available. One thing seems to be missing in the program. Except for the Ministry of Defense project on a supercomputer, about which little is known, there is no project on computer architecture in the program. However, there is work on parallel computer architecture at Grenoble University under Professor F. Anceau and at Lille University under Professor V. Cordonnier. This work has been described in ONR, London, report C-2-84 (19 July 1984).

Details on financial support for the program are not complete. The following are the yearly estimates for several parts of the national projects: VLSI/CAD, F14 million; CAD/CAM, F6 million; software engineering, F18 million; computer-aided instruction, F10 million.

Estimated support for basic research in the Joint Research Projects is as follows:

1. Programming theory (functional, logical, LISP) and man-machine interface (speech, natural language, and pattern recognition) will receive F10 million per year.

2. Communication concurrency and cooperation, database management systems, and submicron VLSI technology will receive F4 million per year. These figures include only a part of the program but they amount to only about $6 million per year.

Based on what is known about the program, it appears to be considerably less impressive than the British Alvey Program. However, one impressive point is that the work on VLSI technology is at the submicron level. Also the French work in robotics theory is among the best in Europe. Since the French were one of the originators of Prolog, it seems likely that they will use it effectively for fifth generation computing systems. Nonetheless, it appears now that it will be many years before fifth generation computer systems emerge from the French industry.

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